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INFORMATION CIRCULAR

MILLING METHODS AND COSTS OF THE MINAS DE MATAHAMBRE, S. A., CONCENTRATOR

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BY

A. R. KIRCHNER, J. V. GALLOWAY, AND W. P. SCHODER

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MILLING METHODS AND COSTS OF THE MINAS DE MATAHAMBRE, S. A., CONCENTRATOR[1]

By A. R. Kirchner,[2] J. V. Galloway,[3] W. P. Schoder.[4]

INTRODUCTION

This paper describing the practice at the concentrator of the Minas de Matahambre, S. A., is one of a series being prepared by the Bureau of Mines on milling methods and costs.

The Minas de Matahambre, S. A., concentrator treats the production of the Matahambre mine and has a capacity of 1,300 tons of copper ore per day by selective flotation. During the year 1930 the heads averaged 4.55 per cent copper, the concentrates 29.20 per cent copper and the recovery was 95.96 per cent.

LOCATION

The concentrator is situated about 6 miles inland from the port of Santa Lucia, on the north coast of the Province of Pinar del Rio, Cuba (fig. 1).

GENERAL DESCRIPTION

The original designs were for a combined gravity and flotation plant, but as flotation methods and equipment have been gradually improved, gravity concentration has been entirely eliminated since 1928. Figure 2 shows a cross section of the concentrator.

The principal changes effected in the concentrator have kept step with improvements in flotation and milling practice, and cover the period from 1922 to the present time. As new developments have been made, they have been adopted at Matahambre whenever possible. Increase in tonnage milled and improvements in milling methods and equipment have effected a reduction in cost per ton milled from $1.508 in 1922 to $0.617 in 1930. Figure 3 is the present flow sheet of the concentrator.

Due to the various changes which have been made in operations, a comparison will be shown, in parts of this circular, between the operations of the year 1930 and work done previous to that time.

The water supply is derived from a small stream passing by the foot of the concentrator. This stream is fed by a few small springs, which very nearly run dry in the dry season, and by water pumped from the mine. These conditions necessitate a recovery of about 75 per cent of the water consumed. A description of the distribution and handling of the water supply will be found further in the circular.

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1 - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6544."

2 - One of the consulting engineers, U. S. Bureau of Mines, and superintendent of concentration, Minas de Matahambre.

3 - One of the consulting engineers, U. S. Bureau of Mines, and ass't. superintendent of concentration, Minas de Matahambre.

4 - One of the consulting engineers, U. S. Bureau of Mines, and chief chemist, Minas de Matahambre.

Power is obtained from the company's power plant stationed at Santa Lucia. This is a steam-turbine generator plant furnishing two 11,000-volt transmission lines running from Santa Lucia to the substation at Matahambre.

ORE TREATED

The ore consists of primary chalcopyrite, associated with pyrite and gangue minerals of shale and quartzite. The chalcopyrite occurs as small veinlets and stringers more or less evenly distributed in the shale and quartzite or graywacke, as it is locally known, or as masses of solid mineral. The pyrite is in small stringers independent of the chalcopyrite or disseminated through it.

The quartzite, while apparently offering more resistance to crushing than does the shale, frees the mineral when crushed, while the shale, especially when wet, tends to be compressed rather than broken and does not free the mineral as easily. However, the crushing of Matahambre ore presents no especial difficulty.

The concentrator head averages 13 per cent of chalcopyrite, 7 per cent of pyrite, and 1.5 per cent of moisture.

The ore is not allowed to remain broken long enough before milling to notice any chemical changes detrimental to its floatability.

BRIEF HISTORY OF OPERATIONS

The mill was originally constructed to operate with capacity of about 600 tons daily by combined gravity and flotation methods.

The combination of gravity and flotation concentration at this time did not permit a selective treatment of all the mineral content of the ore, and concentrates produced averaged below 25 per cent.

Four Butchart primary tables and two secondary tables were operated, recovering an average of 37.5 per cent of the total concentrates, assaying 22.0 per cent of copper.

The flotation of this period was accomplished by a series of pneumatic flotation cells which proved with gradual increase in tonnage to be inadequate. These cells were later replaced by new-type pneumatic cells, and the table concentration was entirely eliminated. The use of sodium cyanide as a flotation reagent was started in January, 1929, with a marked improvement in the concentrates grade.

The change in operations caused a marked improvement in both tonnage and metallurgical results until the latter part of 1929 when a change of character of the mineral content in the heads necessitated a finer grind and a more selective float of the pyrite and chalcopyrite.

To obtain a satisfactory grind it was necessary to install one additional fine-grind mill and classifier. This additional equipment and a prudent use of flotation reagents have made possible the production of a high-grade concentrate with a recovery of approximately 96 per cent of the copper content.

The crushing plant was previously operated with two No. 6 Kennedy gyratory crushers and a No. 3 Telsmith reduction crusher, making 1-inch finished product and crushing about 600 tons daily. Then crushing rolls and screens were added, reducing the finished product to 5/8 inch and increasing the capacity to 900 to 1,000 tons per day. Later the Telsmith was replaced by a 4-foot Symons cone crusher, which resulted in reducing the finished product to 3/8 inch and increasing the capacity to 1,300 tons per day.

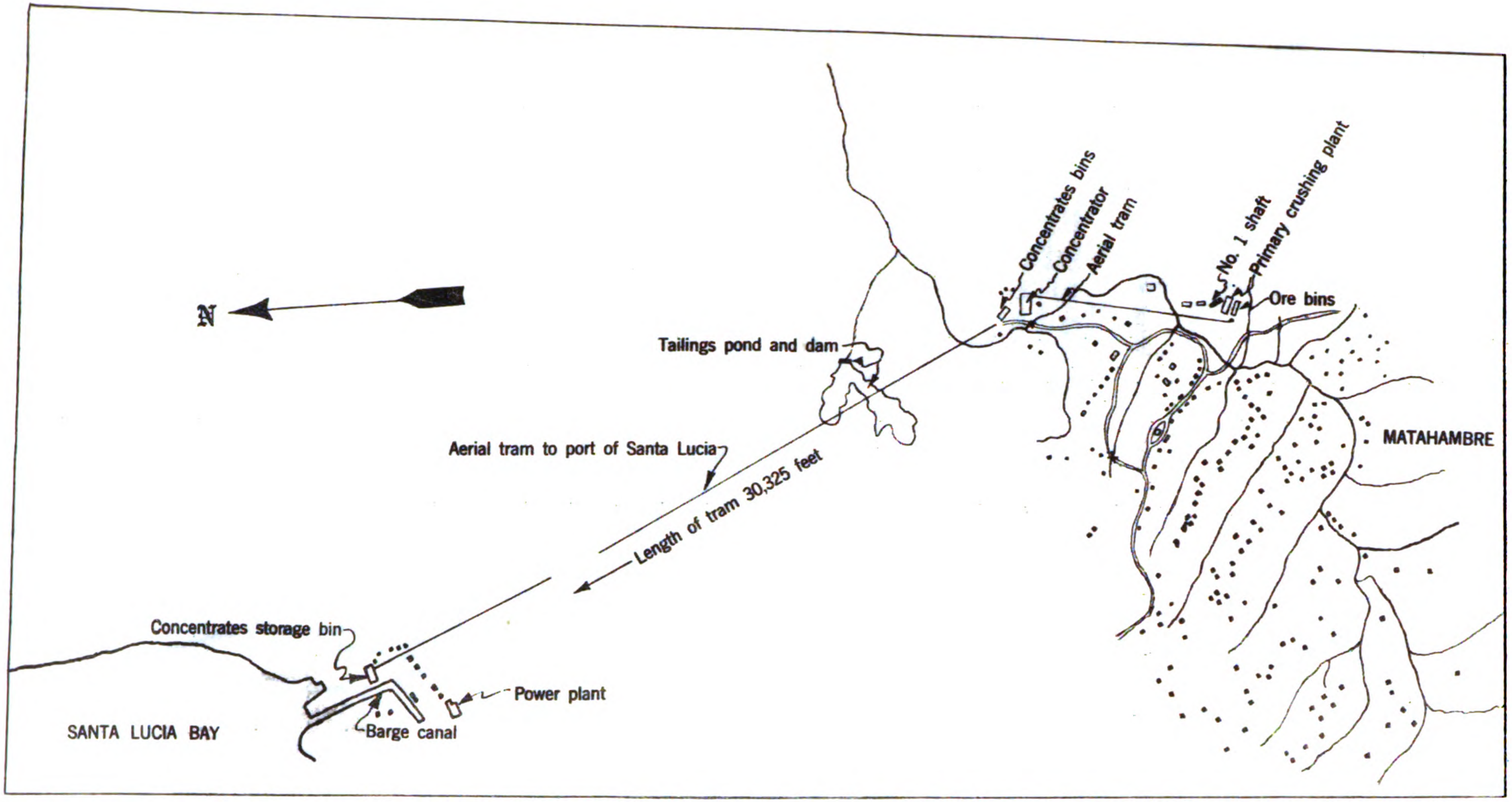

Figure 1.—Plan showing location of concentrator

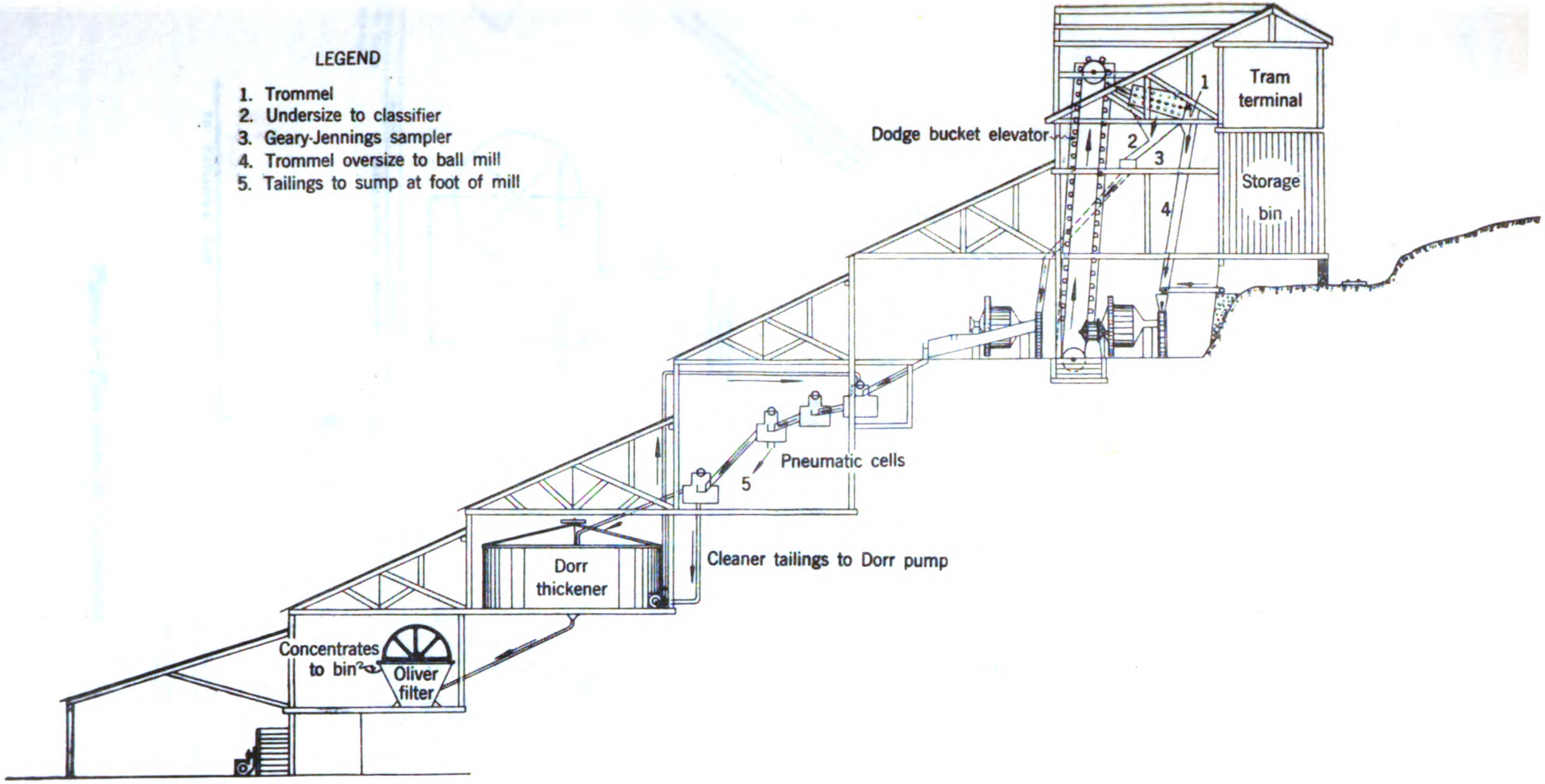
LEGEND
1. Trommel
2. Undersize to classifier
3. Geary-Jennings sampler
4. Trommel oversize to ball mill
5. Tailings to sump at foot of mill
Tram terminal
Storage bin
Dodge bucket elevator
1
2
3
4
Pneumatic cells
5
Cleaner tailings to Dorr pump
Dorr thickener
Concentrates to bin
Oliver filter

Figure 2.—Section of concentrator

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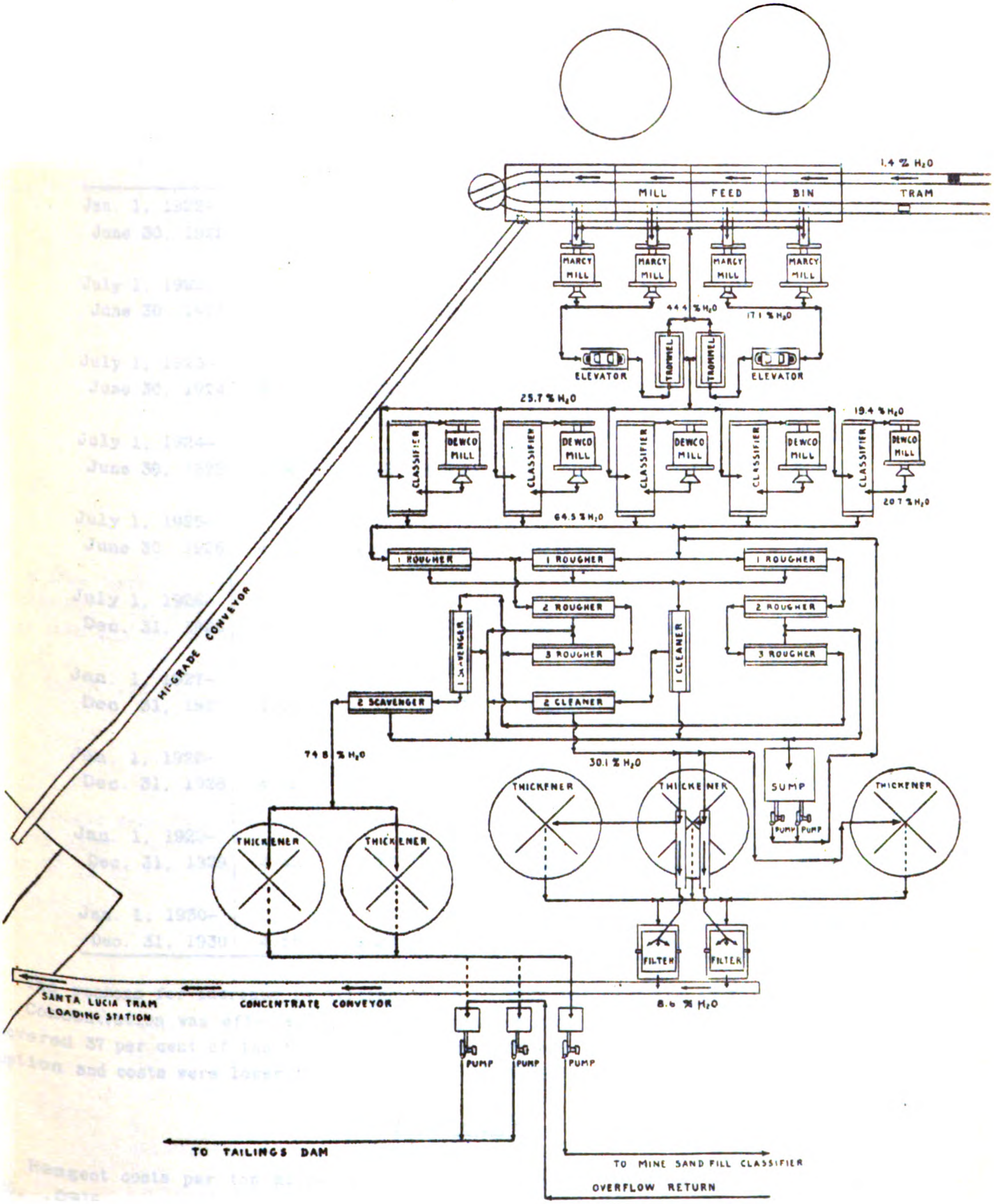

Figure 3.—Flow sheet of concentrator

The following table will give an idea of the various costs and capacity during the years from 1922 to 1930, inclusive:

Costs and capacity of plant, 1922-1930

Year	Copper content, per cent			Short tons milled	Extraction, per cent	Cost per ton
	Heads	Concentrates	Tails			
Jan. 1, 1922–June 30, 1922	5.01	25.36	0.537	90,415	91.3	1.508
July 1, 1922–June 30, 1923	4.61	24.83	0.274	195,192	95.1	1.344
July 1, 1923–June 30, 1924	4.76	24.62	0.265	211,592	95.4	.967
July 1, 1924–June 30, 1925	4.56	24.58	0.274	224,172	95.1	.915
July 1, 1925–June 30, 1926	4.28	24.80	0.152	243,757	96.8	.955
July 1, 1926–Dec. 31, 1926	4.09	23.42	0.178	126,953	96.4	.748
Jan. 1, 1927–Dec. 31, 1927	4.60	23.73	0.271	303,098	95.2	.653
Jan. 1, 1928–Dec. 31, 1928	4.52	24.69	0.220	354,536	96.0	.571
Jan. 1, 1929–Dec. 31, 1929	4.45	27.73	0.239	356,212	95.4	.624
Jan. 1, 1930–Dec. 31, 1930	4.55	29.20	0.216	359,468	96.0	.617

The reasons for increase in milling costs in 1929 and 1930 are as follows:

Concentration was effected by combined gravity and flotation during 1928, and tables recovered 37 per cent of the total concentrates produced, with the result that reagent consumption and costs were lower than during the following years:

Reagent costs

Reagent costs per ton milled have been as follows: 1928, $.0350; 1929, .0691; and 1930, .0916.

The increased cost of reagents per ton milled in 1929-1930, however, was more than compensated for by the reduction in freight and smelting costs on the smaller tonnage of higher-grade concentrates produced.

Increased tonnage during 1929 and 1930 from the section of the mine known as the Ruisenor, during the latter two years, raised the pyrite content of the mill heads very appreciably and necessitated a much more selective float than formerly.

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PRIMARY CRUSHING

The mine skips discharge a minus 12-inch product into a 70-ton bin above the collar of the shaft. The ore is pulled from this bin by two Stephens-Adamson 24-inch apron feeders, each of which feeds a No. 6 Kennedy gyratory crusher. These crushers are belt-driven by 40-hp. motors and reduce the feed from minus 12 to minus 4½ inches, with a combined capacity of 100 tons per hour (fig. 4).

PRODUCT OF PRIMARY CRUSHERS

The product of the primary crushers is as follows:

Inch	Per cent	
+ 1	73.5	
+ 3/4	6.6	
+ 1/2	5.2	
+ 3/8	3.5	
- 3/8	11.2	finished size
	100.0	

This product is passed over a Traylor F. B. 4 vibrating screen covered with a 2-inch grizzly and equipped with 3/4 inch screen cloth. The undersize from this operation goes direct to the storage bin as finished product, while the oversize goes to the next crushing stage.

The screen eliminates wet sticky material which would give trouble all along the line unless removed from the crushing circuit.

INTERMEDIATE CRUSHING

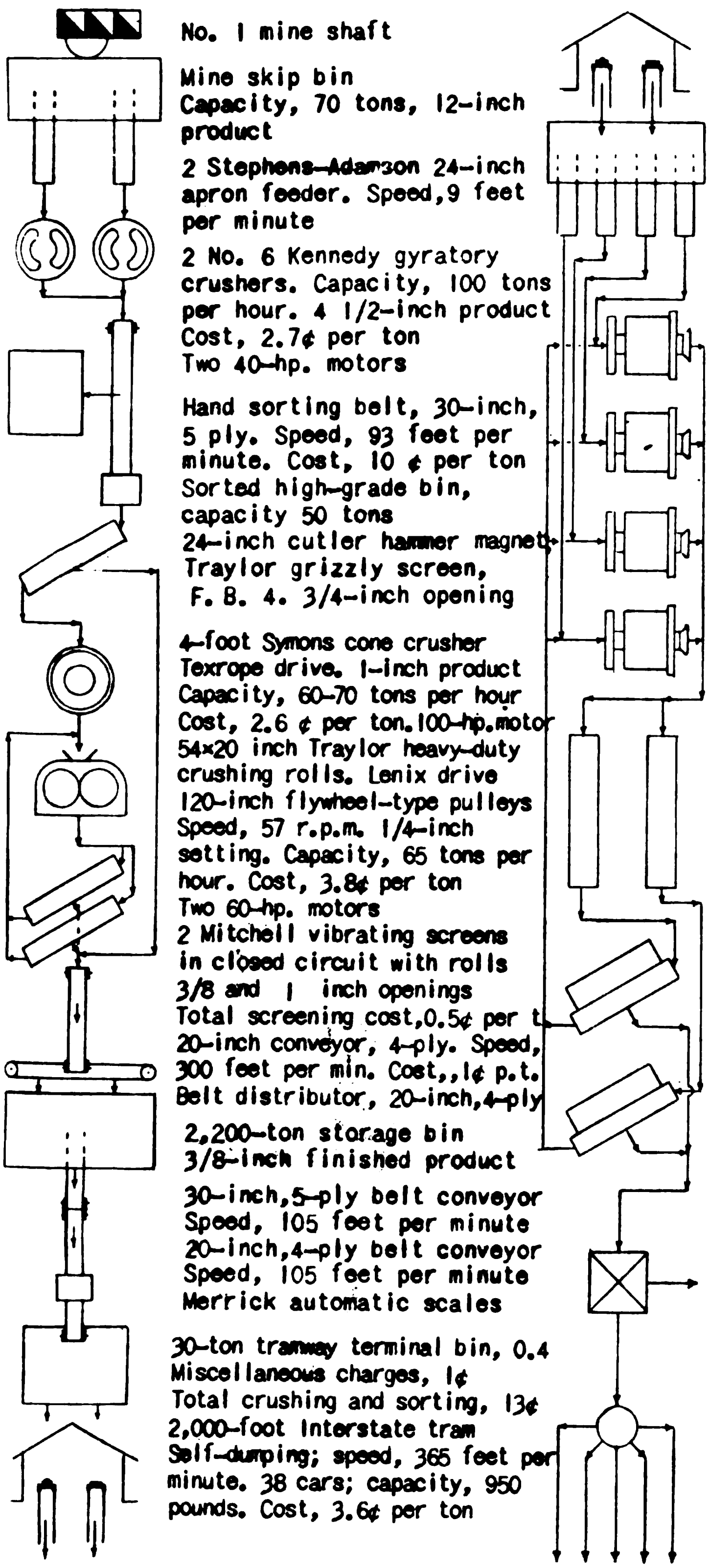
The first stage of intermediate crushing is done by a Symons 4-foot cone crusher, equipped with a coarse bowl and driven by a 100-hp. motor with texrope drive. This crusher is operated with a 3/4 to 1 inch opening and has a capacity of approximately 60 to 70 tons per hour.

PRODUCT OF CONE CRUSHER

The following table shows the cone crusher product:

Inch	Per cent	
+ 1	19.5	
+ 3/4	24.1	
+ 1/2	13.8	
+ 3/8	8.9	
- 3/8	33.7	finished size
	100.0	

The second stage of intermediate crushing is done by a set of 54 by 20 inch Traylor heavy-duty crushing rolls operating in closed circuit with two Mitchell vibrating screens using screen cloth with 3/8 by 1 inch openings. The rolls are equipped with Lenix drives and 120-inch flywheel-type pulleys, and are driven by two 60-hp. motors at 57 r.p.m. The



CRUSHING

No. 1 mine shaft

Mine skip bin
Capacity, 70 tons, 12-inch product

2 Stephens-Adamson 24-inch apron feeder. Speed, 9 feet per minute

2 No. 6 Kennedy gyratory crushers. Capacity, 100 tons per hour. 4 1/2-inch product
Cost, 2.7¢ per ton
Two 40-hp. motors

Hand sorting belt, 30-inch, 5 ply. Speed, 93 feet per minute. Cost, 10 ¢ per ton
Sorted high-grade bin, capacity 50 tons
24-inch cutler hammer magnet
Traylor grizzly screen, F. B. 4. 3/4-inch opening

4-foot Symons cone crusher
Texrope drive. 1-inch product
Capacity, 60-70 tons per hour
Cost, 2.6 ¢ per ton. 100-hp. motor
54×20 inch Traylor heavy-duty crushing rolls. Lenix drive
120-inch flywheel-type pulleys
Speed, 57 r.p.m. 1/4-inch setting. Capacity, 65 tons per hour. Cost, 3.8¢ per ton
Two 60-hp. motors
2 Mitchell vibrating screens in closed circuit with rolls
3/8 and 1 inch openings
Total screening cost, 0.5¢ per t
20-inch conveyor, 4-ply. Speed, 300 feet per min. Cost,, 1¢ p.t.
Belt distributor, 20-inch, 4-ply

2,200-ton storage bin
3/8-inch finished product

30-inch, 5-ply belt conveyor
Speed, 105 feet per minute
20-inch, 4-ply belt conveyor
Speed, 105 feet per minute
Merrick automatic scales

30-ton tramway terminal bin, 0.4
Miscellaneous charges, 1¢
Total crushing and sorting, 13¢
2,000-foot Interstate tram
Self-dumping; speed, 365 feet per minute. 38 cars; capacity, 950 pounds. Cost, 3.6¢ per ton

PRIMARY GRINDING

Concentrator feed
1,300 tons per 24 hours

Concentrator feed bin
Capacity, 1,030 tons- 3/8-inch product. Four 20-inch belt Ratchet conveyor feeders
Speed, 15 feet per minute
1 belt line feeder
1 Geary cyanide feeder

Four 64 1/2-inch Marcy mills
Speed, 25 r.p.m. 15-1 gear reduction. Ball load, 9,000 pounds
325 tons per mill per 24 hours
Circulating load, 360 tons per mill per 24 hours equals 110 per cent
Cost, 12.7 ¢ per ton
Four 100-hp. motors

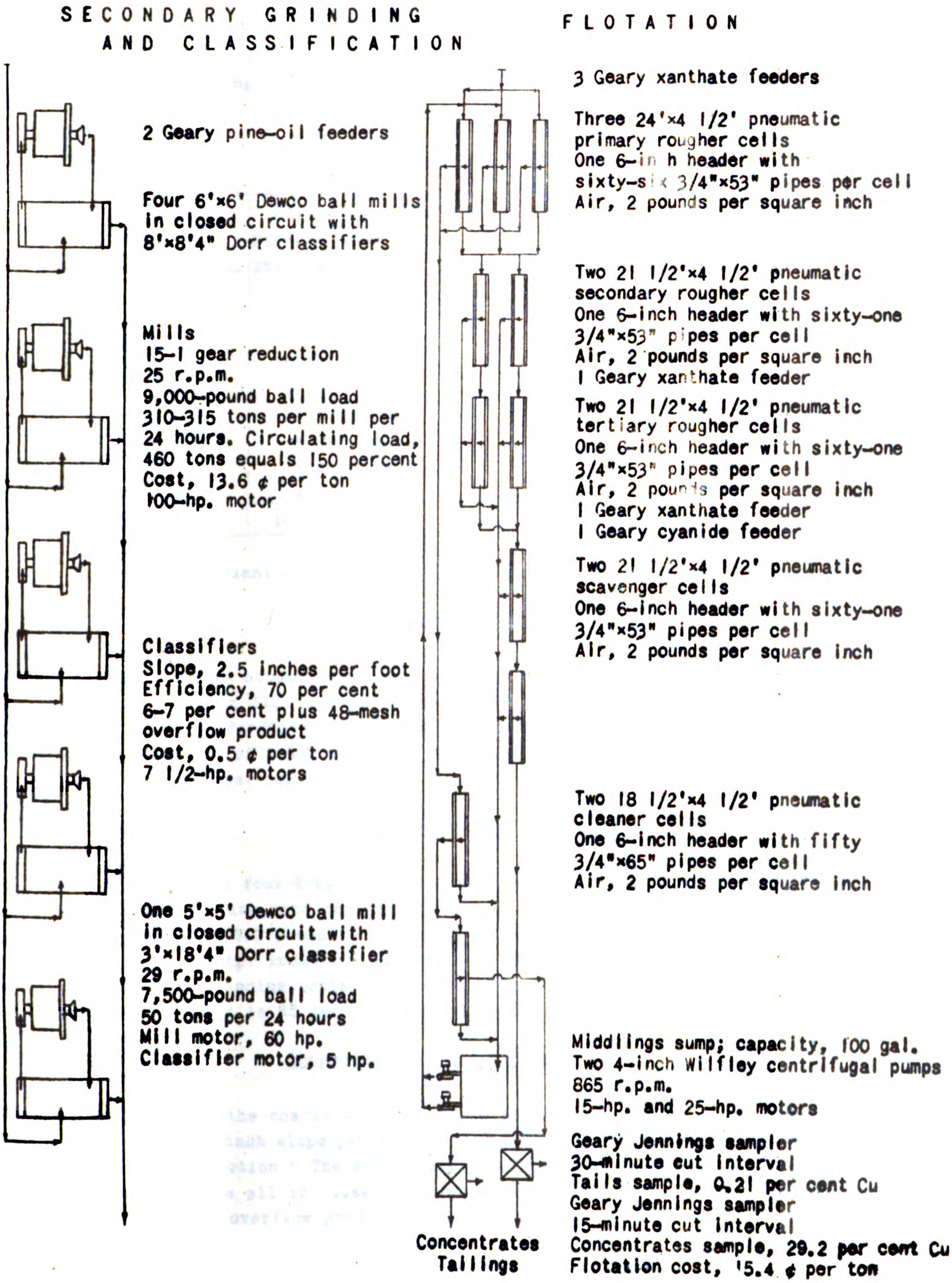
Two 20-inch Goodrich bucket elevators. Ninety-eight 10-inch buckets. 25-hp. motor

Two 48×156 inch trommel screens
Slope, 2 1/4 inches per foot
15 r.p.m. 3-millimeter opening
In closed circuit with mills
Efficiency, 67 per cent
Elevator and trommel cost, 1.1¢ per ton

Geary-Jennings sampler
15-minute cut interval
Head sample
4.55 per cent Cu

Distributor to fine mills

Figure 4.- Flow sheet of crushing and of primary grinding



SECONDARY GRINDING AND CLASSIFICATION

2 Geary pine-oil feeders

Four 6'×6' Dewco ball mills
in closed circuit with
8'×8'4" Dorr classifiers

Mills
15-1 gear reduction
25 r.p.m.
9,000-pound ball load
310-315 tons per mill per
24 hours. Circulating load,
460 tons equals 150 percent
Cost, 13.6 ¢ per ton
100-hp. motor

Classifiers
Slope, 2.5 inches per foot
Efficiency, 70 per cent
6-7 per cent plus 48-mesh
overflow product
Cost, 0.5 ¢ per ton
7 1/2-hp. motors

One 5'×5' Dewco ball mill
in closed circuit with
3'×18'4" Dorr classifier
29 r.p.m.
7,500-pound ball load
50 tons per 24 hours
Mill motor, 60 hp.
Classifier motor, 5 hp.

FLOTATION

3 Geary xanthate feeders

Three 24'×4 1/2' pneumatic
primary rougher cells
One 6-inch header with
sixty-six 3/4"×53" pipes per cell
Air, 2 pounds per square inch

Two 21 1/2'×4 1/2' pneumatic
secondary rougher cells
One 6-inch header with sixty-one
3/4"×53" pipes per cell
Air, 2 pounds per square inch
1 Geary xanthate feeder

Two 21 1/2'×4 1/2' pneumatic
tertiary rougher cells
One 6-inch header with sixty-one
3/4"×53" pipes per cell
Air, 2 pounds per square inch
1 Geary xanthate feeder
1 Geary cyanide feeder

Two 21 1/2'×4 1/2' pneumatic
scavenger cells
One 6-inch header with sixty-one
3/4"×53" pipes per cell
Air, 2 pounds per square inch

Two 18 1/2'×4 1/2' pneumatic
cleaner cells
One 6-inch header with fifty
3/4"×65" pipes per cell
Air, 2 pounds per square inch

Middlings sump; capacity, 100 gal.
Two 4-inch Wilfley centrifugal pumps
865 r.p.m.
15-hp. and 25-hp. motors

Geary Jennings sampler
30-minute cut interval
Tails sample, 0.21 per cent Cu
Geary Jennings sampler
15-minute cut interval
Concentrates sample, 29.2 per cent Cu
Flotation cost, 15.4 ¢ per ton

Figure 5.- Flow sheet of secondary grinding and classification and of flotation

roll shells are of chrome-molybdenum forged steel. The rolls are operated with a choke feed at a ½-inch setting and have a capacity of 60 to 70 tons per hour of material which passes through the screen opening of 3/8 by 1 inch. The circulating load amounts to 30 tons perton hour.

ROLL AND SCREEN PRODUCTS

Size	Roll product, per cent	Cumulative per cent	Screen oversize, per cent	Screen undersize, per cent
+ 1 inch	0.0	-	0.0	0.0
+ 3/4 inch	1.5	1.5	2.2	0.0
+ 1/2 inch	9.1	10.6	15.5	1.5
+ 3/8 inch	29.0	39.6	44.5	7.4
+ 1/4 inch	23.9	63.5	22.4	20.1
+ 6 mesh	16.3	79.8	6.5	30.2
+ 8 mesh	3.6	83.4	0.5	7.9
+ 10 mesh	2.4	85.8	0.4	6.3
- 10 mesh	14.2	-	8.0	26.6
	100.0	-	100.0	100.0

Crushing plant cost, 13 cents per ton.

PRIMARY GRINDING

Primary grinding is accomplished by 64-1/2-inch Marcy mills in closed circuit with two trommel screens handling 325 tons per mill daily. The ball mill load is 9,000 pounds of 4-1/2-inch U. S. Steel Products Co. "Lorain" steel balls and manganese-steel breast liners with a ball consumption of 0.692 pound per ton and liner consumption of 0.54 pound per ton. The cost is 12.7 cents per ton. The mills are driven by 100-hp. induction motors (fig. 4).

SECONDARY GRINDING

One 5 by 5 foot and four 6 by 6 foot Dewco ball mills, each operating in closed circuit with Dorr classifiers, are used for fine grinding. The larger mills handle about 300 tons daily with a load of 9,000 pounds of 3-inch balls and a circulating load of 150 per cent. They are driven by 100-hp. induction motors. The small mill handles only about 50 tons per 23 hours. Secondary grinding costs 13.6 cents per ton. The size of feed is minus 3 millimeters and the discharge is 35 per cent plus 48-mesh material (fig. 5).

SCREENING AND CLASSIFICATION

The discharge from the coarse grinding mills is received by two 48 by 156 inch trommel screens having a 2-1/4-inch slope per foot with 3-millimeter openings. They are belt-driven with a 4 to 1 gear reduction. The efficiency is 67 per cent (fig. 5).

The classifiers are all in closed circuit with the fine mills and attain an efficiency of 70 per cent with an overflow product of 6 to 7 per cent plus 48 mesh. The slope is 2.5 inches per foot, with 27 strokes per minute.

Screening and classifying cost amounts to 1.6 cents per ton.

SCREEN ANALYSIS AND ASSAYS OF SIZES

Flotation	Tyler screen series	% of weight, cum.	Copper		Pyrite		Chalcopyrite		Iron assay, cum.	Sulphur assay, cum.	Insoluble assay, cum.
			Assay, cum.	Location, cum. %	Assay, cum.	Location, cum. %	Assay, cum.	Location, cum. %			
1929											
Heads	+28	1.0	0.70	0.1	0.8	0.1			10.5	1.1	79.3
	+35	7.0	.76	1.2	0.9	1.1			10.7	1.3	77.9
	+48	16.3	.90	3.3	1.1	3.3			11.0	1.5	76.1
	+65	33.0	1.73	12.9	1.9	11.8			12.6	2.7	70.2
	+100	43.7	2.33	23.0	2.6	21.2			13.2	3.9	66.7
	+200	54.7	3.07	38.0	3.7	36.9			14.4	5.9	64.0
	-200	45.3	6.05	62.0	7.4	63.1			18.2	9.9	48.7
		100.0	4.45	100.0	5.3	100.0			16.3	7.3	56.2
Concentrates	+48	0.7	22.2	0.5	30.4	1.6			33.7	37.5	3.6
	+65	8.4	24.4	7.2	23.8	15.1			32.7	36.4	3.5
	100	16.4	25.1	15.5	21.8	27.1			32.3	36.1	3.3
	+200	32.4	27.0	31.6	16.8	41.5			31.6	35.3	3.0
	-200	67.6	28.9	68.4	11.4	58.5			30.8	34.3	3.0
		100.0	27.73	100.0	13.2	100.0			31.3	34.5	3.0
Tails	+20	0.2	0.42	0.4	3.4	0.1			12.3	2.3	78.2
	+28	1.3	0.42	3.0	3.4	1.7			12.3	2.3	78.3
	+35	7.3	0.42	15.5	3.4	7.9			12.3	2.3	78.5
	+48	17.6	0.35	31.6	3.7	15.8			12.4	2.4	77.0
	+65	32.3	0.29	49.4	4.4	28.8			13.2	2.7	73.5
	+100	39.0	0.27	56.5	4.7	34.8			13.3	2.8	70.2
	+200	50.7	0.25	66.3	5.0	49.0			13.5	3.0	65.9
	-200	49.3	0.13	33.7	5.2	51.0			14.1	3.1	59.0
		100.0	0.239	100.0	5.1	100.0			13.8	3.1	62.0
1930											
Heads	+35	1.0	0.14	0.03	2.05	0.3	0.41	0.03	6.9	1.23	85.8
	+48	6.0	0.25	0.33	4.00	3.5	0.72	0.33	7.8	2.38	76.8
	+65	14.2	0.58	1.82	7.22	15.0	1.68	1.82	8 4	4.43	73.3
	+100	25.3	1.53	8.51	8.37	31.0	4.42	8.51	9.1	6.00	68.3
	+150	36.3	2.46	19.57	8.27	43.9	7.12	19.57	10.6	6.89	64.4
	+200	45.5	3.20	31.93	8.15	54.4	9.25	31.93	11.6	7.58	61.9
	-200	54.5	5.68	68.07	5.70	45.6	16.42	68.07	16.4	8.76	46.2
		100.0	4.55	100.00	6.82	100.0	13.15	100.00	14.8	8.24	53.4
Concentrates	+65	1.0	25.1	0.86	6.90	0.75	72.5	0.86	25.1	29.0	12.6
	+100	8.0	27.5	7.52	7.75	6.75	79.5	7.52	28.5	31.8	5.3
	+150	19.0	28.0	18.20	10.95	22.60	80.8	18.20	30.1	34.1	3.8
	+200	30.7	28.3	29.76	12.15	40.50	81.8	29.76	31.0	35.1	3.1
	-200	69.3	29.6	70.24	7.90	59.50	85.6	70.24	29.7	34.1	2.8
		100.0	29.2	100.00	9.20	100.00	84.4	100.00	30.1	34.4	2.9
Tails	+35	1.0	0.15	0.7	2.00	0.31	0.43	0.7	6.7	1.22	72.5
	+48	6.2	0.20	5.9	2.08	2.00	0.58	5.9	7.9	1.31	71.5
	+65	18.1	0.29	24.9	3.11	8.77	0.84	24.9	8.9	1.95	69.6
	+100	32.3	0.29	44.8	4.45	22.33	0.84	44.8	9.8	2.66	69.0
	+150	43.3	0.27	55.2	5.35	36.10	0.78	55.2	10.4	3.12	66.8
	+200	51.8	0.25	61.5	5.94	47.90	0.72	61.5	10.7	3.42	66.4
	-200	48.2	0.18	38.5	6.95	52.10	0.52	38.5	13.6	3.89	58.2
		100.0	0.21	100.0	6.43	100.00	0.61	100.0	12.1	3.64	62.5

AVERAGE ACCUMULATIVE SCREEN SIZES

Tyler screen series	Crushing plant product	Marcy mills discharge	Trommel Over-size	Trommel Under-size	Open circuit classifier Overflow	Open circuit classifier Sands	Dewco mills discharge	Closed-circuit classifier Overflow	Closed-circuit classifier Sands	Dewco mills discharge	Flotation Heads	Flotation Conc'ts.	Flotation Tails
1929													
+½"	1.5												
+⅜"	8.9	0.1	0.3										
+¼"	29.0	1.0	2.1										
+3	38.3	4.5	8.2										
+4	49.0	10.8	16.0										
+6	59.2	15.6	29.5	0.0		0.0		Range					
+8	67.1	22.1	44.4	0.6		1.2	0.0	From To	0.0				
+10	73.4	31.6	65.1	7.6	Range	10.3	1.1	0.0 - 0.0	1.9				
+14	79.2	38.6	72.2	18.2	From To	24.4	6.1	0.0 - 0.1	9.2		0.0		0.0
+20	81.6	46.3	77.6	29.6	0.0 - 0.2	36.6	10.3	0.1 - 0.8	15.4		0.1		0.2
+28	85.5	54.0	81.0	39.0	0.2 - 1.2	41.2	16.2	0.5 - 3.1	21.6		1.1	0.0	1.3
+35	89.9	59.5	84.2	47.2	1.0 - 6.0	53.3	21.4	3.1 -12.2	38.8		7.0	0.1	7.3
+48	93.8	64.5	87.5	54.8	5.0 -11.5	58.0	27.2	9.0 -26.5	53.1		16.3	1.5	17.6
+65	94.4	70.3	89.6	63.4	10.0 -23.0	88.6	59.0	18.4 -40.0	83.9		33.0	9.0	34.1
+100	95.1	73.7	90.2	68.4	23.3 -38.4	90.9	65.3	29.6 -49.2	86.9		43.7	17.4	45.0
+150	96.2	76.3	91.7	71.7	35.1 -49.2	91.4	71.8	37.7 -57.1	89.0		49.1	23.5	55.1
+200	97.0	78.3	95.0	74.7	44.0 -60.0	93.5	79.8	49.0 -64.0	92.4		54.7	34.4	56.0
-200	3.0	21.7	5.0	25.3	56.0 -40.0	6.5	20.2	51.0 -36.0	7.6		45.3	65.6	44.0
	100.0	100.0	100.0	100.0	100.0 100.0	100.0	100.0	100.0 100.0	100.0		100.0	100.0	100.0
H_2O, %	1.5	18.3	17.7	45.0	74.0 -83.0	21.5	22.5	72.0 -82.0	22.5		78.5	30.0	74.0
Solids, %	98.5	81.7	82.3	55.0	26.0 -17.0	78.5	77.5	28.0 -18.0	77.5		21.5	70.0	26.0
1930													
+½"	1.5												
+⅜"	9.1		0.1										
+¼"	28.5	0.9	1.8										
+3	39.0	3.6	4.3										
+4	47.5	8.8	8.8	1.0									
+6	58.7	14.3	15.0	2.0									
+8	66.9	20.9	27.3	3.6					0.4	0.2			
+10	73.6	29.6	44.7	7.3					1.0	0.6			
+14	80.0	37.6	56.1	13.8					3.0	1.4			
+20	81.6	46.3	64.4	23.4				Range	9.3	3.4			
+28	84.4	53.7	70.2	33.3				From To	22.5	9.4			
+35	88.9	59.1	74.1	40.8				0.6 - 1.0	39.5	19.3	1.0		1.0
+48	93.0	64.2	77.7	49.0				6.1 - 7.1	62.3	35.8	6.0		6.2
+65	94.3	68.4	80.3	55.3				16.7 -18.3	74.8	48.8	14.2	1.0	18.1
+100	95.3	72.6	82.7	61.9				32.0 -33.7	83.3	60.8	25.3	8.0	32.3
+150	96.3	75.9	84.3	66.7				43.6 -46.2	87.2	68.5	36.3	19.0	43.3
+200	97.1	78.5	85.8	70.8				54.6 -58.2	89.2	75.0	45.5	30.7	51.8
-200	2.9	21.5	14.2	29.2				45.4 -41.8	10.8	25.0	54.5	69.3	48.2
	100.0	100.0	100.0	100.0				100.0 100.0	100.0	100.0	100.0	100.0	100.0
Solids, %	93.6	82.9	55.6	74.3				34.5 -36.5	80.6	79.3	35.8	69.9	25.2
SP.GR.	2.7	2.1	1.6	1.9				1.3 - 1.3	2.0	2.0	1.3	1.8	1.2
Ratio													
H_2O/Solid	0.1	0.2	0.8	0.3				1.8 - 1.7	0.2	0.3	1.8	0.4	3.0
H_2O, %	1.4	17.1	44.4	25.7				65.5 -63.5	19.4	20.7	64.2	30.1	74.8

HAND SORTING

Hand sorting of high-grade ore was formerly carried on intensively and was of considerable value during the period when the capacity of the concentrator was not adequate to handle mine production. At present hand sorting of high-grade ore has been eliminated, and with the exception of a small percentage of waste, which is sorted out on the belt, the mine ore is now sent direct to the crushing plant as it is delivered from the skips.

FLOTATION

The flotation circuit (fig. 5) is composed of -

3	matless pneumatic	primary rougher cells
2	do.	secondary rougher cells
2	do.	tertiary rougher cells
2	do.	scavenger cells
2	do.	cleaner cells

GRADE OF CONCENTRATES AND TAILS ON FLOTATION BASIS

Cell	Air pressure	Copper in concentrates, per cent	Copper in tails, per cent
#1 rougher	1.6	28.4	0.32
2 do.	1.5	19.7	4.10
3 do.	1.7	19.7	4.80
4 do.	2.0	15.2	1.05
5 do.	2.1	14.3	1.40
6 do.	2.2	9.0	0.30
7 do.	2.0	9.2	0.27
1 scavenger	2.0	5.2	0.24
1 cleaner	2.0	24.1	17.85
2 cleaner	2.4	29.2	21.00

Total air consumption = 9,766 cubic feet per minute.
Total area of cells = 906 square feet.
Total linear feet of cells = 226½ feet.
Total air consumption per linear foot of cell = 43.1 cu. ft.

The flotation cells are supplied by a 20 by 60 inch Connersville Boston-type blower having a net displacement of 10,000 cubic feet of free air per minute at 327 r.p.m. and a maximum pressure of 2-1/2 pounds.

REAGENT CONSUMPTION

Potassium ethyl xanthate - 0.409 pound per ton.
Pine oil - 0.272 do.
Sodium cyanide - 0.031 do.
Lime (90-94% CaO) - 0.206 do.

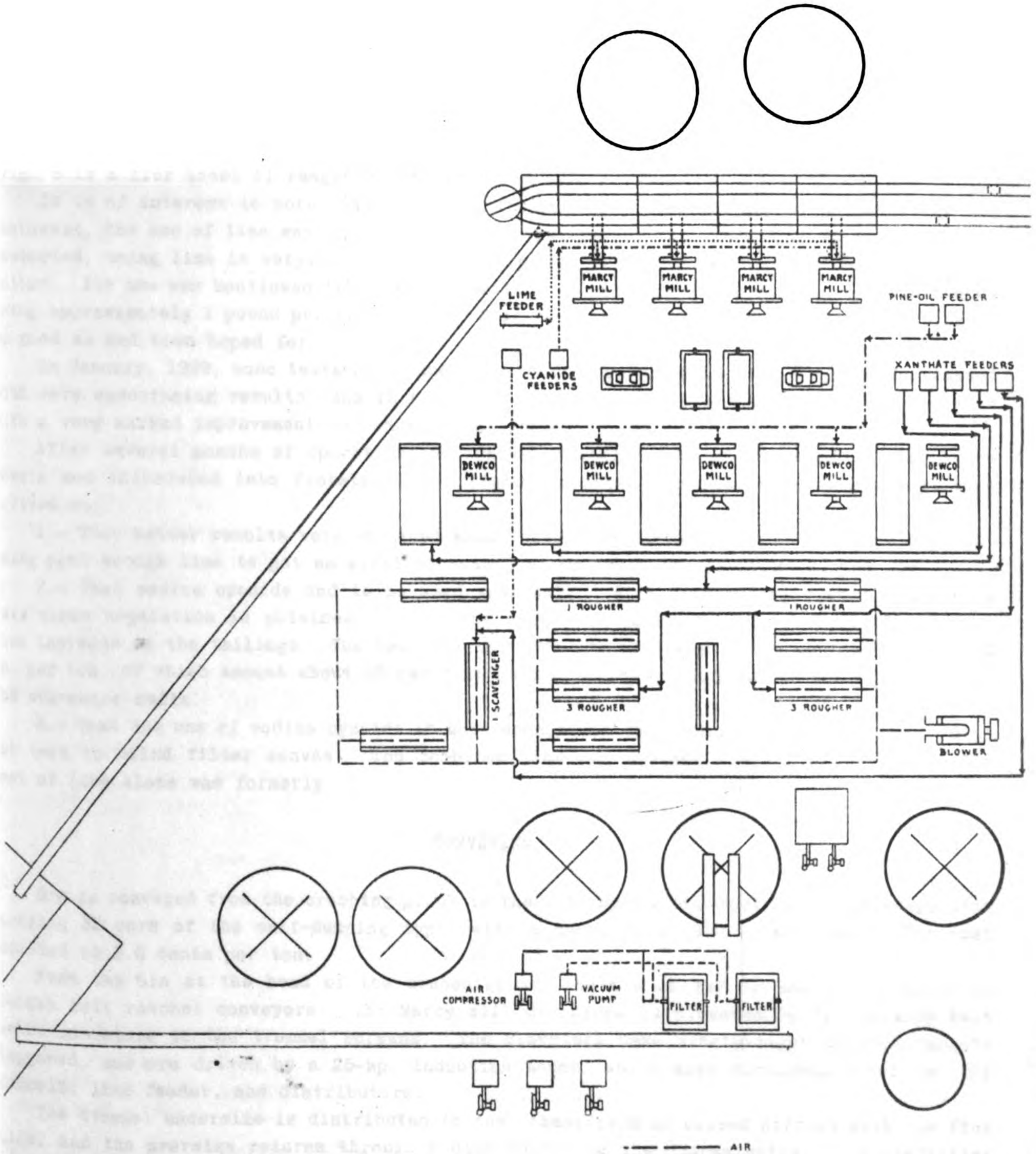


Figure 6.—Flow sheet of reagents and air

Lime is fed by a ratchet-type belt feeder to the Marcy mills.

Xanthate, pine oil, and cyanide are fed by Geary cast-iron stainless steel reagent feeder driven by 1/6-hp. motors. The pine oil goes to the fine mills while the cyanide is fed to the coarse mills and a small amount to the final rougher cells. Xanthate is distributed to various cells. Sixty per cent of the total xanthate is fed to the head of the primary roughers. The reagent cost is 9.5 cents per ton; the total flotation cost is 15.4 cents per ton. (Fig. 6 is a flow sheet of reagents and air.)

It is of interest to note that following the practice of other copper producers in the Southwest, the use of lime was adopted to depress pyrite in 1925. Numerous experiments were conducted, using line in varying amounts from 5 pound to as high as 8 pounds per ton of ore milled. Its use was continued through 1928, with the best results seeming to be obtained by using approximately 1 pound per ton of ore. Fair results were obtained, but they were never as good as had been hoped for.

In January, 1929, some tests were conducted, using sodium cyanide as a pyrite depressant with very encouraging results, and in February, 1929, its use was adopted in the mill work with a very marked improvement in concentrates grade.

After several months of operation, during which sodium cyanide was used in varying amounts and introduced into flotation at different points, the following conclusions were arrived at:

1.- That better results were obtained when using sodium cyanide in an alkaline circuit, using just enough lime to get an alkaline reaction, or approximately 0.2 lb. per ton.

2.- That sodium cyanide had to be used sparingly. With comparatively small amounts a very clean separation is obtained, but as the amount is increased the chalcopyrite losses also increase in the tailings. The best results were obtained when using approximately 0.03 lb. per ton, of which amount about 95 per cent is fed to the primary mills and 5 per cent to the scavenger cells.

3.- That the use of sodium cyanide is more economical and less messy than lime, and does not tend to blind filter canvas. The combined lime and cyanide costs are lower than the cost of lime alone was formerly.

CONVEYING

Ore is conveyed from the crushing plant to the mill by a 2,000-foot Interstate-type tram carrying 32 cars of the self-dumping type, with a capacity of 950 pounds each. The cost amounted to 3.6 cents per ton.

From the bin at the head of the concentrator, the ore is fed to the coarse mills by 20-inch belt ratchet conveyors. The Marcy mill discharge is elevated by two 20-inch belt bucket elevators to the trommel screens. The elevators have ninety-eight 10-inch buckets staggered, and are driven by a 25-hp. induction motor, which also furnishes power for the trommels, lime feeder, and distributors.

The trommel undersize is distributed to the classifiers in closed circuit with the fine mills, and the oversize returns through a distributor to the coarse mills. The classifier overflow passes directly by launders to the flotation circuit.

The middlings from the flotation circuit are collected in a sump, from which they are pumped back to the head by means of two 4-inch Wilfley centrifugal pumps driven by two 25-hp. motors.

DEWATERING AND HANDLING OF CONCENTRATES

The flotation concentrates continue to two 10-inch belt drag classifiers, the oversize of which is spread over the tops of the filters, and the undersize dropped to three Dorr

30 by 10 foot thickener tanks. The spigot discharge passes directly to the filters (fig. 7).

The Oliver 12 by 8 foot continuous filters make one revolution per seven minutes and dewater 3.3 pounds of concentrates per 24 filter hours per square inch of filter surface. Canvas filter cloths are used, having a life of 1,200 filter hours. Vacuum is supplied by a 14 by 8 foot dry duplex vacuum pump.

The filtered concentrates are conveyed by a 20 inch by 215 foot conveyor belt to the loading bin and thence by an aerial tram to the port of Santa Lucia where it is loaded on steamers and shipped to the plant of the United States Metals Refining Co. at Carteret, N. J., for smelting and refining.

DEWATERING AND DISPOSAL OF TAILING

The tailing from the flotation circuit is received by two Dorr 30 by 10 foot thickener tanks (fig. 7).

The spigot discharge is pumped by a 6-inch Wilfley centrifugal sand pump to a Dorr type D. S. D. B. bowl classifier located above the mine workings.

The overflow from the bowl classifier is returned to the concentrator by a 900-foot wooden launder, thence it is pumped by two 4-inch Wilfley centrifugal pumps to the tailings dam. The sands, averaging from 400 to 500 tons per day are fed by two 3-inch, gravity, rubber-lined pipe lines to the mine stopes to be used as fill. When the sands are not needed in the mine the mill tailings from the mill thickener are pumped directly to the tailings dam

SAMPLING

Three Geary-Jennings automatic samplers are located as follows:

No. 1.- Heads sampler; placed at the trommel undersize discharge; 15-minute cut interval.

No. 2.- Concentrates sampler; placed at discharge of No. 2 cleaner flotation cell; 15-minute cut interval.

No. 3.- Trial sampler; placed at discharge of No. 2 scavenger flotation cell; 30-minute cut interval.

All minor sampling is accomplished by the use of hand cutters.

WATER SUPPLY

Figure 8 is a flow sheet of the water supply.

When milling a normal tonnage of 1,300 tons per day, the mill consumes about 600 gallons of water per minute. The ratio of water to solids in flotation feed is roughly 2 to 1, or approximately 35 per cent solids. Due to dilution from various launder sprays and wash water also to the large tonnage of concentrates produced, the ratio of water to solids in the tails is 3 to 1, or 25 per cent solids.

Of the 600 gallons of water consumed per minute, 300 gallons are recovered from the tailings dam, 150 gallons from concentrates and tailings thickener overflows, and the remaining 150 gallons are made up of new water from the stream at the foot of the mill.

The water from the tailings dam is recovered by a single stage, double suction, centrifugal pump. It is collected in a reserve tank with the thickener overflow and fed to four 6 by 8 inch vertical triplex plunger pumps which send this water to two mill supply tanks above the concentrator. The new water is pumped direct to the mill supply tanks.

There is no treatment of the recovered tailings water for purification as it is allowed to settle and is exposed to the sun and air for some time before being used again. The water-supply cost is 1.4 cents per ton.

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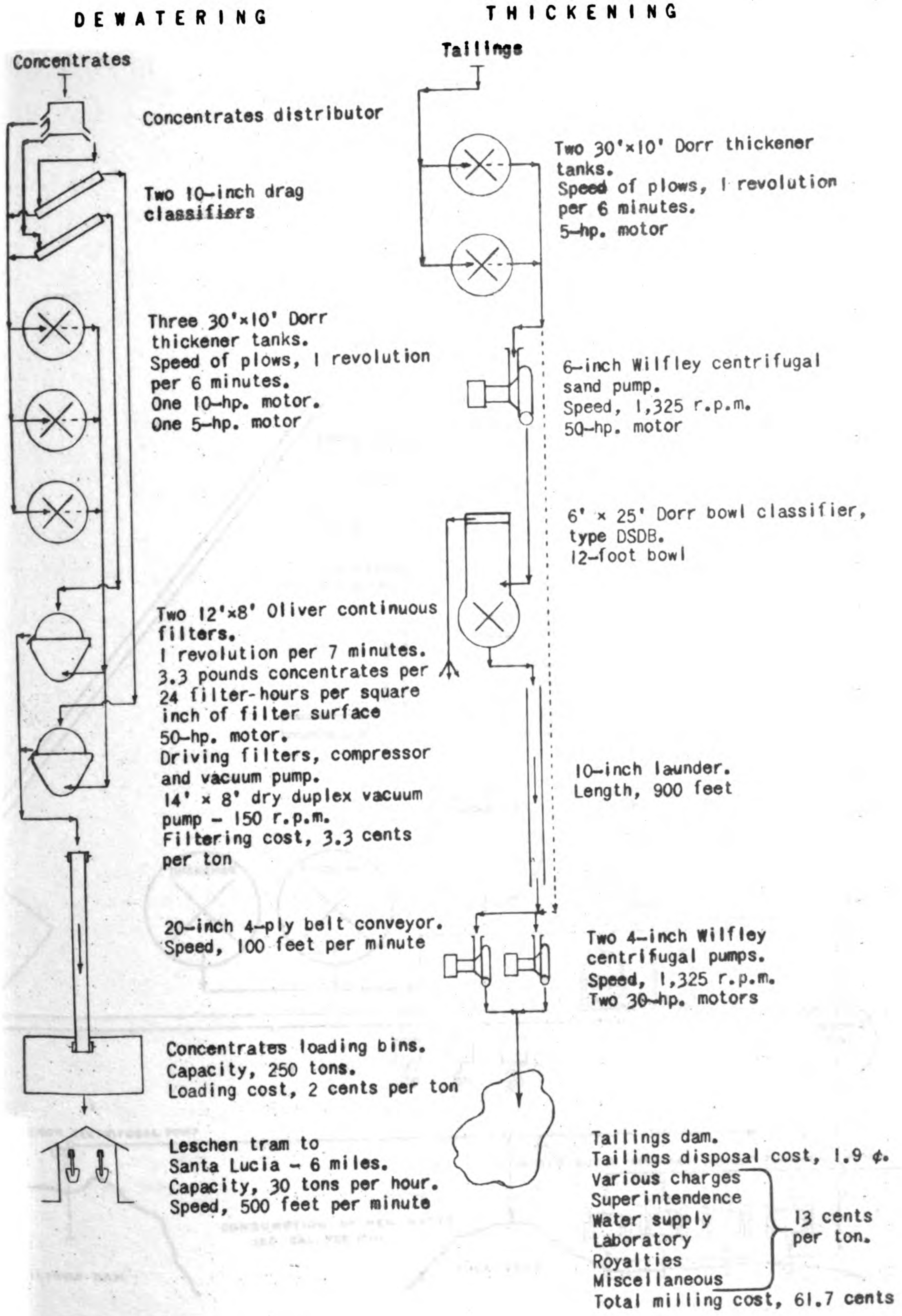
DEWATERING
THICKENING
Concentrates
Concentrates distributor
Two 10-inch drag classifiers
Three 30'×10' Dorr thickener tanks.
Speed of plows, 1 revolution per 6 minutes.
One 10-hp. motor.
One 5-hp. motor
Two 12'×8' Oliver continuous filters.
1 revolution per 7 minutes.
3.3 pounds concentrates per 24 filter-hours per square inch of filter surface
50-hp. motor.
Driving filters, compressor and vacuum pump.
14' × 8' dry duplex vacuum pump - 150 r.p.m.
Filtering cost, 3.3 cents per ton
20-inch 4-ply belt conveyor.
Speed, 100 feet per minute
Concentrates loading bins.
Capacity, 250 tons.
Loading cost, 2 cents per ton
Leschen tram to Santa Lucia - 6 miles.
Capacity, 30 tons per hour.
Speed, 500 feet per minute
Tailings
Two 30'×10' Dorr thickener tanks.
Speed of plows, 1 revolution per 6 minutes.
5-hp. motor
6-inch Wilfley centrifugal sand pump.
Speed, 1,325 r.p.m.
50-hp. motor
6' × 25' Dorr bowl classifier, type DSDB.
12-foot bowl
10-inch launder.
Length, 900 feet
Two 4-inch Wilfley centrifugal pumps.
Speed, 1,325 r.p.m.
Two 30-hp. motors
Tailings dam.
Tailings disposal cost, 1.9 ¢.
Various charges
Superintendence
Water supply
Laboratory
Royalties
Miscellaneous
13 cents per ton.
Total milling cost, 61.7 cents

Figure 7.- Flow sheet of dewatering and of thickening

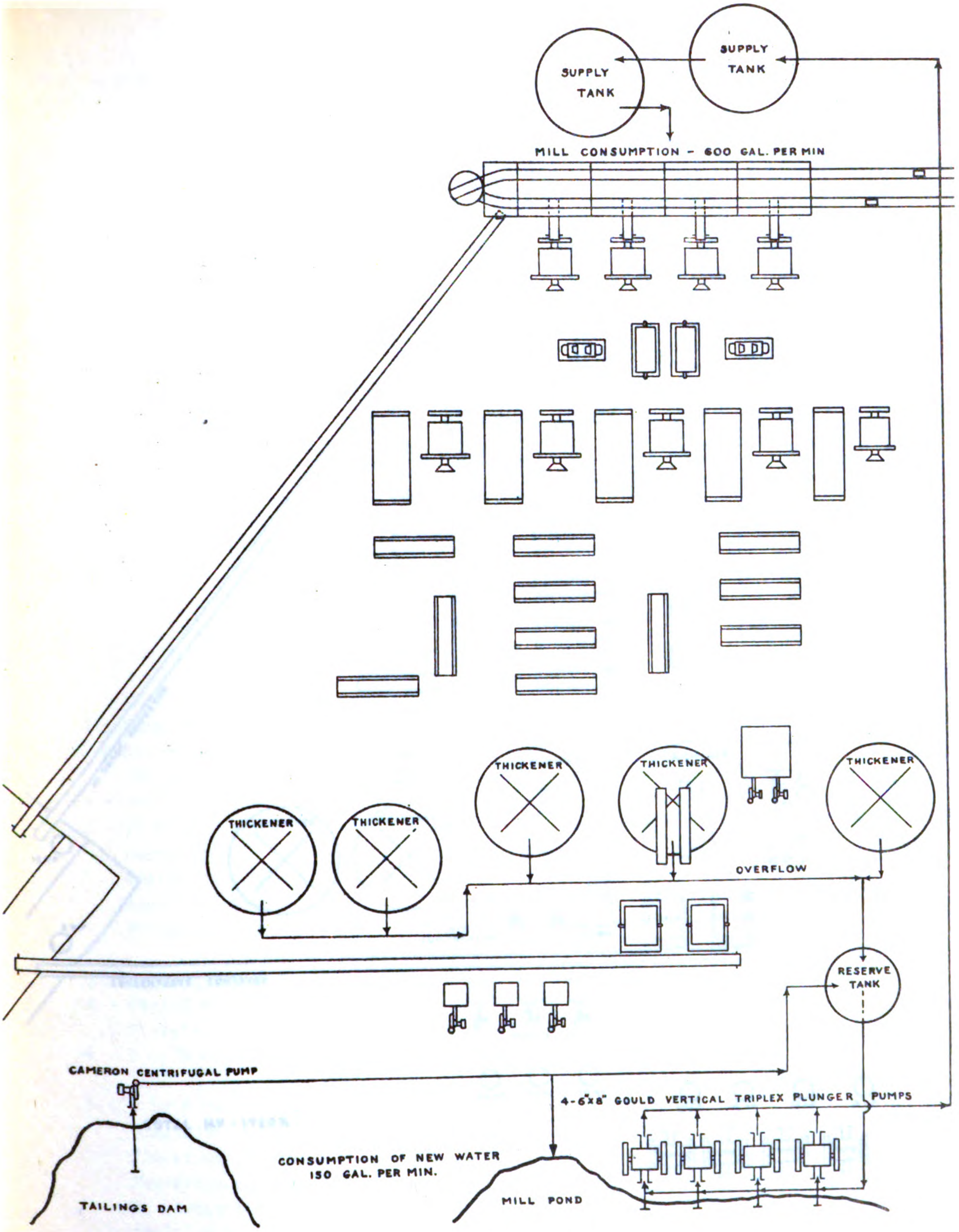

Figure 8.– Flow sheet of water supply

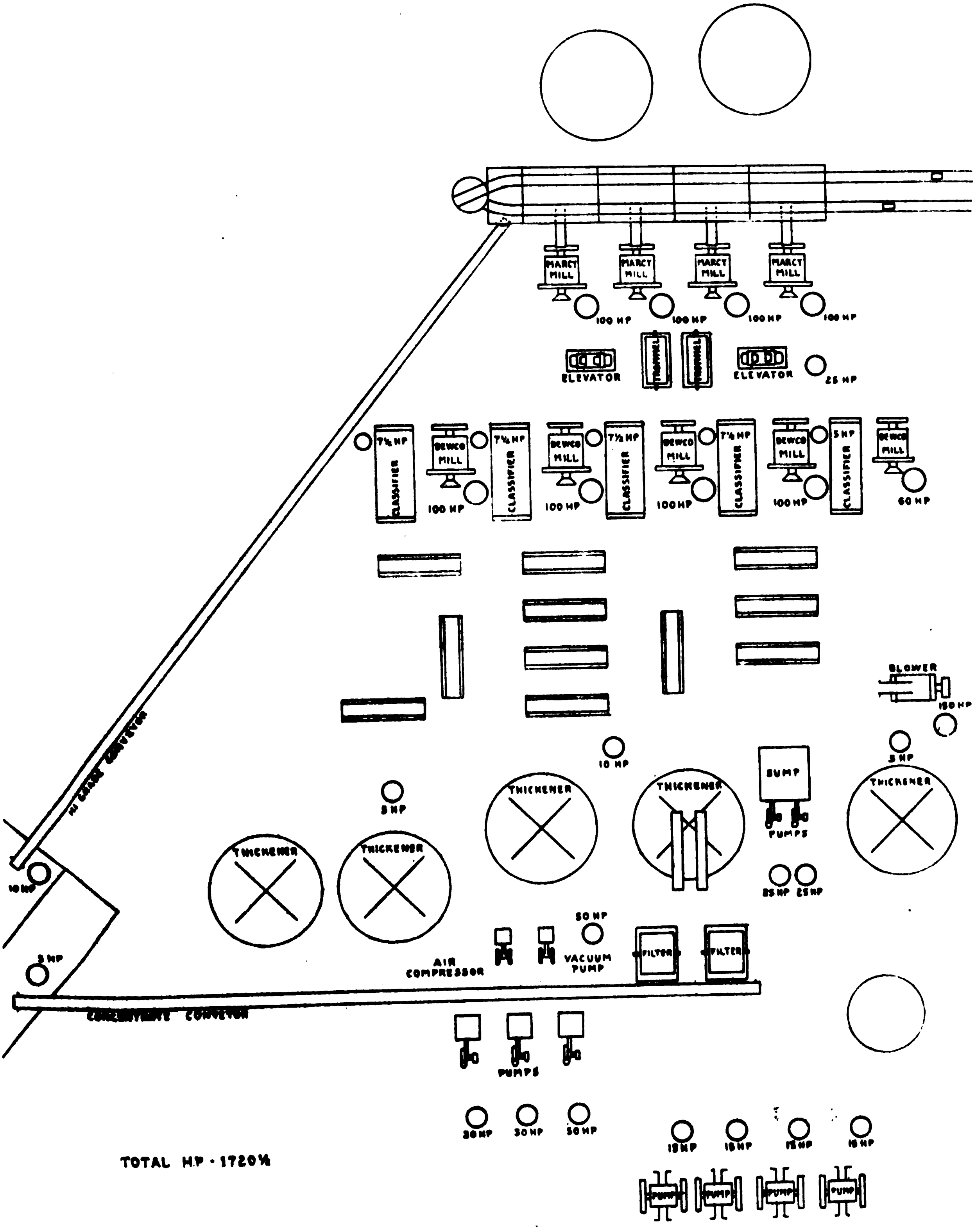

Figure 9.—Flow sheet of power distribution

POWER CONSUMPTION

Power distribution is indicated in the flow sheet Figure 9.

PRIMARY CRUSHING

1929:		
	Tons crushed	362,688
	Total kilowatt hours	929,578
	Kilowatt hours per ton	2.56
1930:		
	Tons crushed	365,374
	Total kilowatt hours	914,088
	Kilowatt hours per ton	2.50

MILLING AND CONCENTRATION

1929:		
	Tons milled	356,212
	Total kilowatt hours	5,577,467
	Kilowatt hours per ton	15.66
1930:		
	Tons milled	359,468
	Total kilowatt hours	5,653,392
	Kilowatt hours per ton	15.73

SUMMARY OF COSTS, 1930

Crushing and sorting	Cost per ton, cents
2 - No. 6 Kennedy crushers	2.7
Sorting belt	1.0
1 - 4-foot Symons crusher	2.6
1 - 54 by 20 Traylor rolls	3.8
Screening	.5
Conveying	1.0
Receiving bins	.4
Miscellaneous charges	1.0
Total crushing and sorting	13.0
Milling and Concentration	
4 - 64-1/2 Marcy mills	12.7
Elevator and trommels	1.1
4 - 6 by 6 Dewco mills)) 1 - 5 by 5 Dewco mills)	13.6
Classifiers	.5
Flotation	15.4
Filtering and dewatering	3.3
Receiving bins	.2
Tailings disposal	1.9
Various charges	13.0
	61.7
Grand total - crushing, milling, and concentration -	74.7